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THESIS

USING VOICE RECOGNITION EQUIPMENT
TO RUN THE
WARFARE ENVIRONMENTAL SIMULATOR (WES)

by

William Joseph McSorley III

March 1981

Thesis Advisor: G. K. Poock

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Using Voice Recognition Equipment to Run the Warfare Environmental Simulator (WES)

by

William Joseph McSorley III
Lieutenant Commander, United States Navy
B.A., Princeton University, 1970

Submitted in partial fulfillment of the requirements for the degree of

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ABSTRACT

A great deal of study has been conducted in the last ten years concerning the use of voice recognition equipment with computers. It was hoped that its use would reduce the required entry time and error rate, and improve the man-machine interface between the user and the computer.

There are many potential applications for such voice recognition use in the military, and specifically in the area of Command, Control and Communications (C^3). War games are often used today to test the effectiveness of C^3 technologies, and WES is one such war game.

This paper will assess the feasibility of using voice recognition equipment to run WES by comparing the results of an experiment employing both voice and manual typing input modes. The results show that in this particular task typing does a somewhat better job than the buffered voice mode, while unbuffered voice has very poor results.

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I. INTRODUCTION

The cost of computer hardware has dropped dramatically in recent years, and the use of computers throughout our society has skyrocketed to help us manage the glut of data which we are often presented and to solve the increasingly more complex problems of the present and future. Historically, data has been entered into the computer by keypunch, which can be slow, monotonous and error-filled for all but the very well-trained. Researchers have looked for a better, more efficient man-machine interface than the keypunch, and as early as the 1950's they realized that the most natural type of communication which we as humans use is speech. So why not simply speak to a computer as you would to a fellow worker and have the computer perform whatever task you have directed?

A. A BRIEF HISTORY OF VOICE TECHNOLOGY

1. General Background

Voice recognition systems have received quite a bit of interest since the 1950's, mainly during the past fifteen years. Automatic speech recognition, per se, is concerned with automatically determining linguistic messages spoken to the voice recognizer by comparing them to acoustic data stored in the recognition system. Both industry and the military have decided to study the feasibility of incorporating

interactive voice recognition systems in their computer operations in order to have a more natural interface with the computer, to increase the speed of data entry and retrieval and thereby increase throughput, and to lower the input error rate. A voice recognition system, using one's natural language, would certainly seem to have the potential for reducing errors at the man-machine interface. In addition, the higher-level personnel in industry and the military, those specifically who must make the important decisions and who most need the decision-making aid of the computer, are those least likely to sit at the keyboard and use the computer. So it was thought that voice interaction would help these high-level personnel become more direct users of the systems on which they depend.

Interactive voice recognition systems (i.e., those which give either a vocal or a displayed response to a verbal input) can be basically divided into two categories: isolated word recognizers and continuous speech recognizers. Isolated word recognition systems were the first type developed and by far the easier of the two to engineer and construct. An isolated word recognizer, with a limited vocabulary of x number of words or utterances (short phrases), must simply recognize the utterance spoken to it and respond as programmed. This recognition is accomplished by "training" the system prior to its use. Anyone who will be using the system trains it by repeating the various vocabulary words a

number of times, usually between five and ten, with different inflection, stress, pronunciation, etc., while in a "training mode." The parameters of the pronunciation of each utterance are then averaged and stored in the digital speech processor memory of the system. Then when a word or phrase is spoken to the recognition system, its parameters are compared digitally to all those stored in memory and hopefully a match is found and the proper response made by the computer [1].

While this indeed sounds like a complex process, consider what the continuous speech recognition system must do. In addition to all the above it must be able to recognize word sequences and digit strings. It must be able to find boundaries between words, or segment the utterance either explicitly or implicitly by trying to fit together sequences of word pronunciations before the final classification process [2,3]. It is difficult to analyze the beginnings and endings of words unless adjacent words are known; it is much easier to recognize words spoken in isolation, or separated by short pauses, than those with no pauses between them. However, it is very unnatural for humans to pause after speaking each word in a sentence, and although the first isolated word recognition systems have been in use since 1972, further study into advanced systems has continued.

2. Some Past Uses of Voice Recognition Systems

Beginning in 1972, there have been several successful uses of interactive voice recognition systems in industrial

settings. These have been strictly isolated word systems up to this time. It has been found that by using voice systems to interact with a computer, a worker's hands and eyes are both free to continue their tasks. It is thereby possible to increase the speed of data entry by the worker not having to stop what he is doing, write down or directly enter data and then return to where he previously left off. Voice also cuts down on the number of errors often encountered in this process or in other processes where the first worker must relay information to a second worker who then enters what he heard (perhaps incorrectly) into the data system.

Airlines were the first to use voice recognition to input data to a computer for the correct routing of baggage to various aircraft. It was found very efficient to allow the baggage handler to input data by voice, freeing his hands and eyes to look at and handle the pieces of luggage. Banks have been able to accomplish paperless transfers of funds, dividends, retirement payments and the payments of bills by simply speaking the dollar amount to be transferred to the voice recognition system. Quality assurance checks on manufactured goods have been greatly simplified and speeded up in many cases by allowing inspectors to use their hands and eyes for the inspections while simultaneously inputting data to a computer by voice. In addition to these few examples of discrete speech recognition there are many other

areas where voice recognition systems either are currently being used, or could easily be used in the future [1,4].

B. STUDY AND TESTING OF VOICE RECOGNITION SYSTEMS

Although discrete speech recognition systems have been, and are in use, research has continued on both the discrete and continuous speech systems. Probably the largest such study undertaken to date has been the Advanced Research Projects Agency (ARPA) five year $15 million Speech Understanding Research (SUR) project begun in 1971. This project was designed to provide a breakthrough in the handling of spoken sentences, by the use of higher-level linguistic information and specific task-dictated constraints on what could be said [5]. It was thought that this was an important project because of increased industrial interest in speech recognition, government interest in future programs, the work of several foreign countries in the field, and projected future widespread applications. In 1978 the projected ten year sales of 2.5 million speech processing units ($4.8 billion) seemed to lend a great deal of credence to these points [5].

The SUR project was concerned with understanding as opposed to simply word recognition. By understanding was meant having the system interpret an utterance and respond correctly. The project was designed to be highly task oriented, and to have speech analyzed and interpreted in

the context of a task, rather than interpreting each word or component of the utterance individually [3,6]. Other goals included a working vocabulary of 1,000 words for the system and accuracy of 90 percent averaged over several different speakers.

The SUR project was designed to develop several intermediate "throw-away" systems rather than to work toward one carefully designed ultimate system. With this in mind there were five main system contractors and four specialist contractors engaged in the research at the start of the SUR project. The five main contractors were Bolt, Beranek and Newman (BBN); Carnegie-Mellon University; Lincoln Laboratory; System Development Corporation; and SRI International. The four specialist contractors were Haskins Laboratory; Speech Communications Research Laboratory; Univac; and the University of California at Berkeley [7].

Approximately one-half way through the five year project three systems which seemed to be farthest along in meeting ARPA's goals were selected to continue the project. When SUR ended in September 1976 it was generally agreed that it had greatly advanced the state of the art in continuous voice recognition and that cost-effective speech input was a plausible scientific and technical goal [6]. One of the final three systems called HARPY, developed by Carnegie-Mellon University, met all of ARPA's initial goals. Using a vocabulary of 1,011 words and five different speakers,

HARPY achieved a total sentence accuracy (i.e., all words correct) and semantic accuracy (i.e., correct response accuracy) of over 90 percent for the specific task of document retrieval [5,6]. The other two systems tested, HWIM (for Hear What I Mean, by BBN) and HEARSAY II (by Carnegie-Mellon) fell somewhat short of the stated objectives.

Another more recent study of voice technology was done for the Rome Air Development Center, Rome, New York. In this project the use of voice systems to input cartographic data for the Defense Mapping Agency Aerospace Center was studied. It was found that voice input was fast, more accurate and easier to use than the paper, pencil and keypunch that were presently in use. In addition, the voice system eliminated the need for skilled typists to interact with the computer. It was found that the speed of data entry for inexperienced personnel was much higher for voice than for those at a keyboard who were not skilled typists, indicating that much less training was required to operate the voice recognition system than to skillfully use the keyboard [8]. For this particular task, and for others as well, since voice is the most natural mode of communication, it was hoped that its performance level would be higher than manual input with a minimum of training.

A final example of a recent voice recognition study [9], carried out at the Naval Postgraduate School (NPS), compared the uses of manual and voice inputs to run a distributed computer network. Using twenty-four military officers as

subjects operating on the ARPA Network, and using a fixed scenario of instructions, it was found that voice input - again with minimal voice practice - was 17.5 percent faster than manual typing input, and manual input had 183.2 percent more entry errors than did the voice input. It is presumed that an even greater difference would have been recorded had experienced voice input subjects been used.

C. POSSIBLE MILITARY USES OF VOICE RECOGNITION SYSTEMS

The military is also carefully studying the use of voice interactive systems for many varied applications. The author has encountered several possible Navy applications which are prime candidates for voice recognition use. In the area of tactical data systems, normally data has been directly entered from remote sensors or by an operator at a keyboard, and then either acted upon or retrieved by the operator. Voice systems can greatly facilitate the operator's data entry or retrieval by allowing him to interact vocally with the system rather than requiring a skilled typist at the keyboard. This should reduce the time needed for interaction and the possibility of many errors [6].

A study at NPS addressed the possibility of using a voice recognition system as the interface between a ship's Tactical Action Officer (TAO) and the Naval Tactical Data System (NTDS) computer in order to reduce reaction time. This study also postulated the use of a voice synthesizer to output the information requested from the computer. The authors felt

that there is an incompatibility between a discrete speech system and other communications which the TAO uses. During a period of tension, it might be difficult to use discrete speech with one system and continuous modulation on others. It was also felt that a discrete speech recognition system would not be compatible with the rapid pace of a TAO's duties [10]. Further study should be done in this area.

Naval aviation is a field where there are a great many possibilities for the use of voice systems. One study [11] reported investigating the feasibility of using a Voice Recognition and Synthesis (VRAS) system with the Advanced Integrated Display System (AIDS) on Navy aircraft. VRAS, a software package of real-time voice processing routines, when used with the AIDS cockpit information system would provide a much improved man-machine interface between the pilot and the onboard computer. The voice interactive system in this case could handle complex tasks encountered in an airborne environment and could free the eyes and hands of the pilot for other tasks. Some possible uses would include selecting a missile verbally vice manually, and having this confirmed verbally, thereby allowing the pilot to fly a better intercept profile. The system could be used for reporting (e.g., "report airspeed"), data entry, systems checks where VRAS reports when a checklist is complete, and so on. It is thought that this might help reduce the clutter of instrumentation and fault warning displays in the aircraft. In addition, it was even

postulated that a speech recognition system together with an adequate display system could substitute for a second man in an F-14/A-6 type aircraft. It could save space, and reduce weight, fuel consumption, manpower, training and the life cycle costs of an aircraft [6].

Other military areas where voice recognition systems could be used might include command centers, combat information centers on board Navy ships, inputs for weapons fire control systems, and air traffic control. Very interesting and relevant research is presently being done at NPS on the possibility of using voice systems for the military photo interpreter and for use with the Joint Chiefs of Staff (JCS) Emergency Action Message (EAM) system. Appendix A lists voice recognition studies which have been, or are presently being conducted at NPS.

Although a good deal of research has been done on the feasibility and design of interactive voice recognition systems, much is yet to be done. For instance, how do you improve the acoustic phonetic analysis ability of a system so that it is able with a high degree of accuracy to understand continuous voice commands from a large number of people? Is there really even a need for continuous voice recognition systems? They would certainly be nice, and they are much more "natural" than isolated word systems for a human user, but what is the opportunity cost of developing them? These questions are now being answered and will be answered in the future, thanks in great part to the impetus of the SUR project.

II. BACKGROUND

The area of Command, Control and Communications, or C^3, has been an integral part of human existence since the beginning of civilization, although it has gone by different titles and has had slightly different shades of meaning. There is a great deal of difficulty even now in defining and quantifying this "new" area of C^3. It is definitely a process, it involves equipment and individuals, and also goals or missions. To this author C^3 is a process or means by which a military commander (or civilian authority) exercises authority and direction in allocating scarce resources (e.g., money, troops, ships, etc.) in order to achieve organizational goals in the most efficient manner possible.

A. VOICE RECOGNITION IN C^3

In his action of directing or allocating resources, in performing the vital elements of C^3, the commander must interact with individuals and equipments. Several of the military examples of speech recognition study in Section I fall within this area of C^3. These examples included the TAO-NTDS interface, use of voice recognition in a command center or CIC and use of voice recognition by a pilot in the cockpit of an aircraft. Each of these certainly depicts a command and control situation where voice recognition systems might be of use. Additionally, the example [9] of the increased speed of

input and lower error rates provided by voice input while controlling a distributed computer network certainly points to the possible use of voice for C^3 purposes.

Several features make speech recognition potentially very useful in the area of C^3. It is felt that there will be a closer coupling of the commander with the system he depends on when using speech inputs. Most commanders would never tie themselves down to a keyboard during any crisis or battle situation. With the use of speech recognition and a wireless microphone there would not be this feeling of being tied down. There would also be more centralization of control in a crisis situation. This would result in increased speed of interaction with the system, and a more effective use of the new support technology available [6].

In a C^3 environment, voice systems could certainly be used for data input and retrieval. A Task Force commander would directly use such a system for information management and evaluation, as an aid in decision making, and for decision dissemination. The closer a commander can be to the system upon which he bases his decisions, the better the quality of his decisions should be, with greater avoidance of serious error. Command language also is of limited complexity with a rather large vocabulary to cover many possibilities, and this should suit it well to a voice recognition system.

B. WARGAMING/SIMULATIONS FOR MEASURING C^3 EFFECTIVENESS

One of the major problems in the C^3 arena has been how to measure the effectiveness of a C^3 system. Since C^3 must function in distinctly different conditions (e.g., peacetime, periods of crisis, conventional or nuclear war) this becomes increasingly more difficult. How does one gauge or measure whether a Command and Control system will function in a nuclear war? More importantly, perhaps, is whether the system will function in those transition times between each of these major conditions.

It is certainly not sufficient to measure effectiveness by simply comparing the "output" of one system with that of another. For example, for a new communications system simply having a higher message handling rate or a lower bit error rate than an existing system does not necessarily improve the C^3 capability. The effectiveness of a system in improving the chances of victory in battle, or for achieving organizational goals, makes it a better C^3 system. Since it is often not possible to test a system under such conditions, simulations and models are often used.

War games are a type of simulation frequently used by the military to evaluate C^3 effectiveness. Through the use of a war game evaluators and commanders can determine with a great deal of accuracy the effectiveness of present and proposed C^3 technologies under simulated warfare conditions. Such war games often allow for replication so that a scenario

basically can be replayed using different C^3 strategies in order to evaluate the effectiveness of one system as opposed to another. War games are a very cost-effective means of running such an evaluation under realistic conditions using experienced players.

1. Manual and Voice Inputs for Games

The most realistic war games today, those which are able to be run at a near real-time speed, which are able to enter and disseminate a large volume of sensor and fire control data, and which are able to regularly and quickly update displays are either computer-assisted or computer-run war games. Manual war games, although generally no less accurate than computer-assisted games, are usually very slow moving, require many extra participants to record data and often quickly become monotonous and tedious. In a computer-assisted war game commands are generally input at a keyboard as is usually the case for most other computer-type functions, as previously noted. It is certainly plausible to consider using voice input devices to run such war games.

If war games are to be used to evaluate C^3 effectiveness, one facet of such an evaluation certainly could be any increase in effectiveness provided by a voice recognition system as opposed to conventional manual input. In fact a war game can be used as a vehicle for testing the concept of using voice recognition equipment in any number of other military applications where high speed of input and low error

rates are necessary. It was with this thought in mind that the author decided to develop and conduct an experiment comparing the use of voice and manual inputs to run a Naval war game. The author chose the CINCPACFLT version of the Warfare Environmental Simulator (WES) as the war game to use in this experiment. WES was chosen mainly because it is easily accessible from the NPS Remote Site Module (RSM) and because the author was already somewhat familiar with its operation.

C. DESCRIPTION OF THE WARFARE ENVIRONMENTAL SIMULATOR [12]

The Warfare Environmental Simulator (WES) is a computer-assisted war game which runs on a DEC KL-2040 or a PDP-10 computer at the Naval Ocean Systems Center (NOSC), San Diego, California. WES is a two-sided interactive game in which Blue and Orange sides can define, structure and control their own forces. The game is strictly a Naval war game which employs approximately 80 player commands to control the platforms and sensors engaged in the game.

Each command position in a WES game contains a graphics terminal situation display, an alphanumeric terminal presenting status board displays and another alphanumeric terminal for input of player commands. This player terminal acts as both an input and an output terminal. While the system is in the input mode output messages are queued. The color graphics display is driven by a PDP-11/70 which is interfaced with NOSC's KL-2040 or PDP-10 via the ARPANET. WES operates under either the TOPS-20 or TENEX systems.

The WES game is a combination of three major processes, called BUILD, FORCE and WARGAM. Each of these is an integral part of the war game and must be initialized and used prior to and during game play. The BUILD process is used to create and modify a database of game objects such as ships or shore bases. With BUILD a player may add, delete or modify a file of game objects in the database. This will normally be done prior to game play when determining the forces needed for the game. The database contains values for ship classes, shore bases, aircraft types, missiles, sensors and weapons.

The FORCE process creates the actual game scenario to be used. With FORCE game objects from BUILD files are organized into task hierarchies for use in the game. FORCE specifies the actual names and classes of ships, their initial locations, courses and speeds along with any associated aircraft, sensors and weapons. FORCE allows a player to create new game scenarios, to modify a scenario, to change numeric parameters or to input or delete items from a scenario. Contingency plans which might be used during a game can also be created and entered into the specific game database by using FORCE.

WARGAM actually runs the interactive game based on the chosen scenario and the commands input by the players. Once initiated it responds to player commands, generates both the graphics and the status board displays and updates these displays each game minute. The WES graphics display at NPS uses a GENISCO display processor/CONRAC CRT to display in

color the graphic situation display. This display includes grid tick marks, background maps, NTDS symbology for friendly, neutral and enemy tracks, lines of bearing for passive sensors, weapons envelopes and game time.

Six alphanumeric status board displays are controlled by WARGAM and are shown on a user terminal one at a time. The player controls the status board functions by depressing appropriate keys at the terminal. The six status board displays include the following: active track status, passive track (ESM) status, friendly ship status, friendly air status, friendly shore bases status and flight status. These displays then contain all the status information which one would expect to find in the CIC on a surface ship.

The WES commands which players use to control the war game are highly formatted in terms of syntax and input parameters. Two types of errors are possible when inputting a command. First, the syntax may be incorrect. In this case an immediate warning is issued on the terminal saying that the command cannot be parsed. This should alert the player to check his command and then reenter it correctly. Second, a command might order some impossible action (e.g., addressing a ship not in the game). No immediate warning is issued in this case since the order parses correctly. However, when execution of the order is attempted it cannot be carried out and this fact is displayed on the terminal for the player. When an order is entered correctly, the system responds that the order has

been entered; this indicates that the order was parsed and sent on for execution, but not that there is no possible discrepancy in the order (as noted in the second error case above).

It was with this game of WES as described above that the author conducted his voice/manual input experiment. The details and background of the experiment are described in Section III and its results in Section IV following. The conclusions drawn from the data collected address the feasibility of using an automatic voice recognition system to run computer-assisted war games in general, and WES in particular.

III. EXPERIMENTAL DESIGN

A. CONCEPT OF THE EXPERIMENT

The basic goal of this experiment was to test the feasibility of operating WES by using voice inputs rather than the customary manual inputs. This would be accomplished by having a number of test subjects individually enter valid WES commands for BLUE forces while the game was running, recording the time necessary to successfully enter the commands and the number of errors committed with voice and manual input, and then analyzing the data to see whether one entry method was superior to the other. Although the WES game would be running, the only commands entered would be for the BLUE forces and therefore there would be no interaction between BLUE and ORANGE, or actual "game play." BLUE-ORANGE interaction was not considered necessary for the goals of this experiment. However, it was considered important to have WES running during the experiment, rather than having the subjects merely type out the WES commands or speak them to a voice recognizer, so that the actual interaction with the WES input/output player terminal would be accomplished as in a two-sided war game.

In order to run WES, as noted in Section II, game forces must be assigned and a scenario established. The author chose to use an existing WES scenario with its associated forces

for the experiment. The CUBA scenario was chosen due to its relative simplicity and yet entirely adequate forces for the experimental goals. In this scenario three United States warships, aircraft carrier ENTERPRISE, guided missile destroyer BERKELEY and nuclear submarine STURGEON are opposed by three Soviet warships and one merchant ship in a setting similar to the 1962 Cuban missile crisis. The test subjects would command the ships and forces of the BLUE task force by using a fixed series of commands provided to them.

It was necessary to establish a basic vocabulary which the subjects would use to enter the player commands to WES. This vocabulary had to be complete enough to allow formulation of any of the WES commands [12] which might be necessary during play of a game. The vocabulary had to contain all the scenario specific words (e.g., ENTERPRISE, BERKELEY) which might become necessary in order to command those BLUE forces in the CUBA WES scenario. Also, the vocabulary had to be compatible with both the voice and keyboard methods of entry. The vocabulary which was used is considered sufficient to run any basic WES game involving the forces in the scenario. The total vocabulary amounted to 162 words or short phrases (Appendix B).

B. EQUIPMENT USED

1. <u>Hardware Description</u> [13]

For the experiment a Threshold Model T600 discrete utterance voice recognition unit manufactured by Threshold

Technology, Inc. was used. The T600 is an electronic speech recognition device which automatically recognizes utterances of up to two seconds in duration. These utterances can be of several words in length as long as they do not exceed this time duration. Since it is a discrete, or isolated speech recognition unit there must be a short pause (at least .1 second) between utterances. The T600 allows up to 256 separate voice utterances to be stored in memory. As noted above, 162 utterances were the total vocabulary for this experiment.

The Model T600 terminal used in this experiment consists of an analog speech preprocessor, microcomputer, CRT/keyboard unit, magnetic tape cartridge unit, remote voice input unit and noise-cancelling microphone. The speech preprocessor and microcomputer are contained in a main terminal processor unit. The speech preprocessor accepts spoken input from the remote voice input unit, extracts speech parameters and converts these to digital signals which are then processed by the microcomputer. The microcomputer compares these input signals with stored reference patterns to determine which vocabulary words were spoken. The reference patterns for all the vocabulary are established during a training phase when the user trains the voice recognizer by repeating each of the vocabulary utterances ten times. If a close match is found between an input speech utterance and a reference vocabulary

pattern, the utterance is "recognized" by the T600. It then sends to the user's computer the appropriate output string of characters associated with the recognized input.

The T600 has three types of memory which the user may modify: speech reference patterns, prompt character strings and output character strings. As noted above the speech reference patterns are formed when the user trains the voice recognizer by repeating the vocabulary utterances a number of times. The prompt character strings are input by a user at the keyboard and are displayed on the CRT for each utterance to prompt the speaker when he is training that particular utterance. The output character string, also initially entered via the keyboard, is the actual output sent to the user's computer over a communications interface by the T600 when an utterance is recognized. The recognized utterances are sent exactly as if they had been typed in at the keyboard. When spoken each of the utterances is echoed on the CRT as a visual display for the operator.

The speaker uses a noise-cancelling microphone plugged into the remote voice input unit while speaking to the T600. This microphone allows the T600 to be used in noisy areas. The placement of the microphone by the speaker is very important during both the training and recognition phases with the T600. Accurate recognition may decrease if the microphone is moved from one position to another in relation to the speaker's mouth. It should be placed in front of the lips

but not touching them, and slightly to the side of the speaker's mouth. The microphone should just touch the lower lip when the lip is extended forward as far as possible. If the microphone slips from this position while speaking, it should be readjusted before continuing.

Data in the T600 memory is stored in the main terminal processor unit. In conjunction with this the magnetic tape cartridge unit, a digital tape recorder, is used to store this memory data on a tape cartridge and then to recall it from the cartridge whenever desired. The tape, once recorded, can be used to quickly retrain the terminal with the user's speech patterns and specific vocabulary. This is very useful when the terminal is used repeatedly by a number of different users.

For this experiment two additional pieces of equipment were connected in parallel with the T600 described above. An ADM 31 Data Display Terminal with print much smaller than that of the T600 was used so that the longer commands input by the user would entirely fit on a single line rather than "wrapping around" as they would on the T600 CRT. It was felt that this would eliminate one possible source of confusion for the test subjects. Additionally, a Miniterm Model 1203 was used in order to obtain a hard copy printout of all the voice and manual input commands. This was necessary to accurately count and differentiate between the types of input

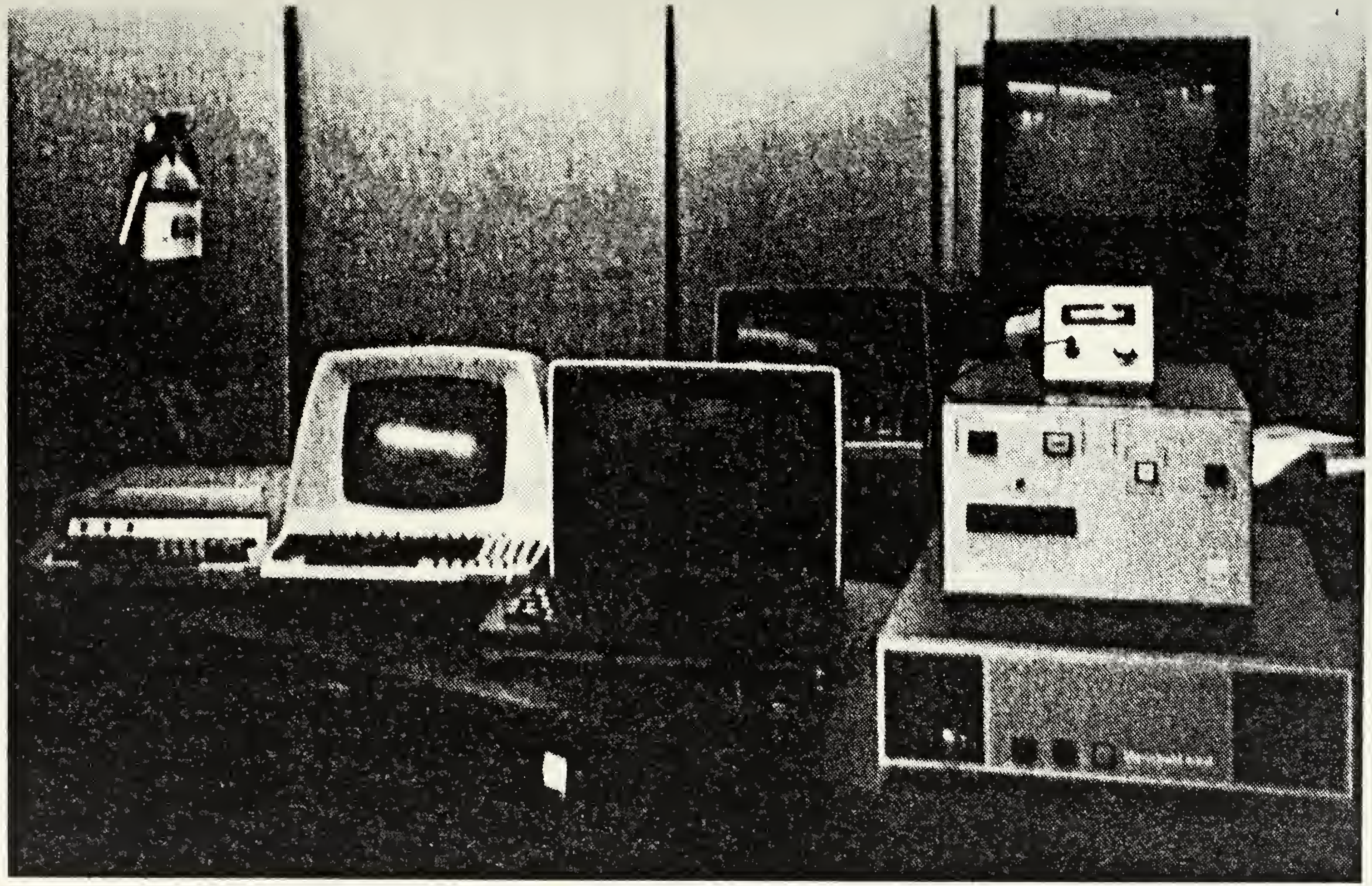
errors. This will be discussed at greater length in Section IV. The entire equipment set-up as used in the experiment is shown in Figure 1.

2. Available Input Modes

The speed of entry and number of errors associated with three different input modes were to be evaluated in the experiment. Each subject would type the BLUE player commands at the ADM 31 terminal, would enter the same commands using the unbuffered voice mode of the T600 and would enter the commands via the T600's buffered voice mode. The order of the input modes was varied from subject to subject in order to eliminate any bias which the ordering might have introduced.

In the typing mode with WES there is no way of correcting any error once it is typed prior to sending it to the game for execution (i.e., no backspace or erase). This is quite important since a single error will invalidate an entire WES command. If an error is made it is best to immediately type a carriage return (entering the incorrect order), and then retype the order correctly and enter it into the system. By doing this time is saved which would otherwise be wasted while completely entering a command already containing an error, and the possibility of committing further errors in this same command is eliminated.

The unbuffered voice input mode to WES is very similar to this. The T600 will send the ASCII character stream associated with any recognized voice input to the



l. to r: Miniterm, ADM 31, T600 CRT/Keyboard, microphone, remote voice input unit, magnetic tape cartridge unit, main terminal processor unit.

Figure 1. Equipment Used

user's host computer without the user being able to correct any "incorrectly recognized" spoken input. No editing is possible in the unbuffered voice mode of operation, and therefore, like typing, when an error is noted it is best to enter the command at that point and then reenter it correctly. In contrast to this the T600's buffered voice mode allows the user to verify his input stream, make corrections to it if necessary and then transmit it to the host computer. The T600 stores the utterances in an internal buffer which may be modified and the contents of this buffer are sent to the host in a "block" when the user transmits them.

C. SELECTION OF SUBJECTS

1. Backgrounds

Twelve subjects who participated on a voluntary basis were chosen for the experiment. Eleven of the subjects are military officers (six Navy, four Air Force and one Army) in paygrades 03 - 05, and one is a civilian professor at NPS. Ten of the military officers are members of the Command, Control and Communications (C^3) curriculum at NPS and the eleventh is on the faculty. Two of the twelve subjects are female Naval officers.

All subjects had previously had at least a brief exposure to WES while at NPS. However, only one subject, the female faculty member, was considered to be experienced with WES. In addition, all the subjects had at least minimal

experience with voice recognition systems, with six of the subjects considered "experienced" with voice systems. This experience was established for four subjects by participating in a six month controlled voice recognition longitudinal study, and for the two faculty members by continuous use of voice systems over a prolonged period of time (more than three years for the civilian professor). This breakdown of six experienced subjects and six inexperienced with voice recognition systems was planned in order to determine whether prior experience would be a significant factor in determining the preferred method of command input to WES. A synoptic background of the twelve test subjects is contained in Appendix C.

2. Initial Training

Each of the subjects met individually with the author and was given a typing ability test. This consisted of a five minute typing exercise (similar to that given to a GS-2 typist) during which the subject was instructed to type two given paragraphs totalling 21 lines as quickly and accurately as possible without error correction. A subject's speed in words per minute (wpm) was then calculated with a scoring table approximately using the formula wpm = total characters/25. A certain number of errors, increasing with the number of gross words per minute typed, was permitted, with any errors in excess of this number resulting in .2 wpm per error subtracted from the final typing speed.

The typing ability test was given to determine whether there was a clear cut distinction between typists and non-typists among the test subjects. Although one subject typed below 20 wpm and two subjects were above 40 wpm, nine of the subjects were grouped between 21 and 39 wpm. Due to this close grouping and the rather short length of the WES commands this difference in typing speeds was not considered important. The typing test used, along with its scoring matrix, is shown in Appendix D.

Each of the subjects next trained the T600 voice recognition unit using the WES vocabulary of Appendix B. This training was accomplished by having the subjects repeat each vocabulary utterance ten times while in the T600 training mode in order to optimize the stored reference patterns for their individual speech variations. The average time required to train the 162 utterance vocabulary was 94 minutes, with the shortest time being 69 minutes and the longest 116 minutes.

Once the training was completed each utterance was repeated three additional times while in the T600's recognition mode to check for recognition accuracy. If at least two of each three vocabulary utterances were correctly recognized, the utterance was considered to be properly trained. If not, that vocabulary word was then retrained and again checked for accuracy. On the average each subject retrained five utterances (three being the least number retrained and

nine the highest), with phonetically similar expressions such as HARM/ARM, with/list, back/track/attack and dive/five causing the most difficulty.

D. CONDUCTING THE EXPERIMENT

For the experiment the author had compiled a list of 20 basic WES commands for the CUBA scenario. These 20 commands (Appendix E) totalled 272 voice utterances and used 67 of the 162 vocabulary utterances considered necessary to run an actual WES war game. The author had further divided these 20 commands into five shorter groups of four commands each (Appendix F). The commands in these five groups were arranged so that each group would be of approximately the same length. (Those utterances in Appendices E and F which consisted of more than one word are highlighted as they were for the subjects during the experiment.)

Each subject would be required to input the list of 20 commands and the five shorter lists of commands by the three methods of typing, unbuffered voice and buffered voice. The order of the input methods and the lists of commands used was randomly varied from subject to subject to eliminate any bias. When inputting the short lists, whether by typing or voice the subjects were given a brief rest between each of the five lists. The use of the 20 command list and the group of five lists with breaks between each was designed to see whether fatigue, frustration, or the prospect of having a

long or short task ahead might have any relevance on the results of the different entry methods.

The conceptual design of the experiment is shown in Figure 2. This is a three-factor nested design with repeated measures over the tasks. Each subject is nested within only one of the levels of experience.

Once each subject had finished training the T600 he met at a later time with the author to conduct the actual experiment. At this point the subjects were given a brief overview of what they would be doing along with a verbal set of instructions (Appendix G). Since in some cases it had been several weeks since the initial voice training all the subjects were given a copy of the WES vocabulary in order to refresh their memories. In addition the subjects were provided a list of practice commands (Appendix H) with which they were allowed to train until they felt at ease and confident with the use of the voice recognition system.

After each subject felt satisfied with his practice the experiment was run. The entire list of 20 commands and the five groups of commands, depending on the order used, were entered into the WES game via the three different input methods. While using the voice recognition modes, if an utterance was misrecognized four consecutive times or an abnormally large number of times throughout the experiment, the author stopped the clock and had the subject retrain that

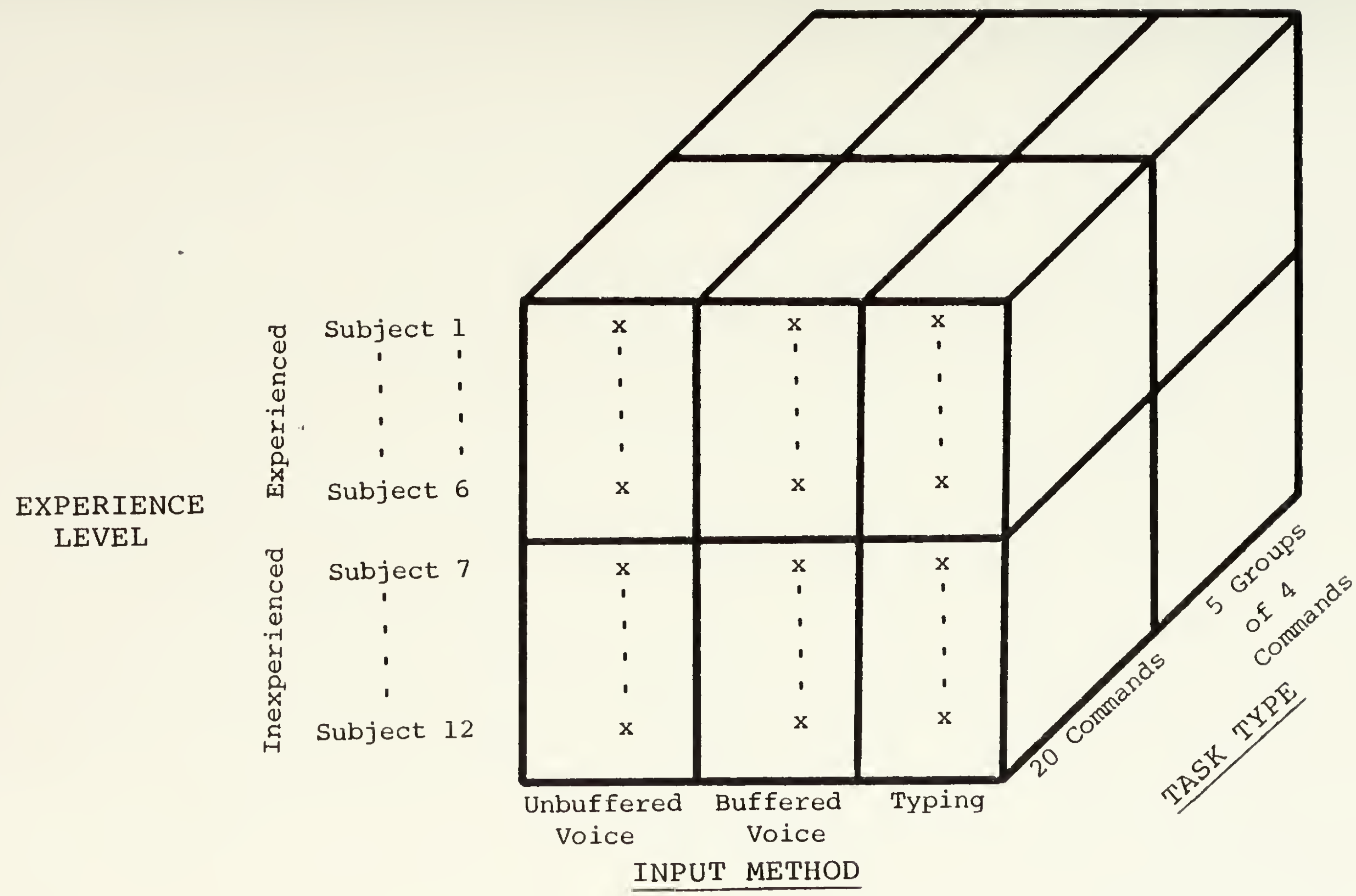


Figure 2. Conceptual Design of the Experiment

utterance rather than continue to struggle against the system. This was done on six occasions. The results of the experiment are contained in Section IV.

IV. PRESENTATION OF DATA

A. DATA COLLECTION TECHNIQUES

During the typing and the unbuffered voice modes of the experiment the Miniterm was used to keep a typescript of all commands entered by the subjects and the responses of the WES game. During the buffered voice mode the Miniterm was not used since the only commands which would have been printed were those already corrected by the subject and sent containing no errors from the internal buffer. Instead the author manually recorded errors during this phase.

The following measures of performance were recorded during all the trials: 1) the time required to complete a specific scenario, and 2) the number of input command errors. Input errors were divided into two types, recognition errors and operator errors. Recognition errors were those encountered when the T600 "thought" the subject said one thing but he had actually said another. This type of error was not applicable to the typing mode. An operator error was any other type of error committed which was not attributable to the T600 (e.g., a typing mistake, the operator forgetting to say "space" after a number, the operator saying "for" (and having it recognized as "4") rather than "for the," etc.).

In analyzing the data the author was interested in the actual number of errors committed. Therefore every single error was counted as a separate error. For example, if the subject made one typing error, or had one voice utterance misrecognized during a command, this was counted as one error. However, if the subject committed two typing errors in the same command before entering the command, this was counted as two errors although they only invalidated a single command.

B. GENERAL RESULTS

As noted earlier, each set of 20 voice commands contained 272 voice utterances. Each subject was required to input the total 20 commands four different times by voice (i.e., the list of 20 commands by buffered and unbuffered voice, and the five groups of four commands in the same manner). Therefore, if no voice errors had been committed, the twelve subjects would have inputted a total of 13,056 voice utterances during the experiment. However, the occurrence of both recognition and operator errors, and having to reenter the commands which contained these errors, resulted in a somewhat greater number of voice utterances for the experiment. (The author did not physically count this total number.) There were 982 recognition errors recorded during the experiment.

After analyzing the typescript from the unbuffered voice portion of the experiment, it was found that of the 67

utterances used to form the 20 WES commands, 46 of these utterances had been misrecognized at least once for some other vocabulary utterance. Twenty-one of the utterances were never misrecognized by the T600. In the buffered mode only the numbers of recognition errors were recorded rather than the misrecognized words since the author was not able to keep an accurate record of these.

There were more total errors with each of the voice input modes than with the typing mode. The following data were found when looking at total number of errors (recognition errors + operator errors): typing, 169 total errors; buffered voice, 542; and unbuffered voice, 701. These figures show that the typing mode had 68.8 percent fewer total errors than did the buffered voice mode, and 75.9 percent fewer errors than the unbuffered voice mode.

All of the subjects, regardless of typing ability, had been inputting data via a keyboard for at least five quarters while at NPS, while only six were considered experienced in voice entry. In addition, subjects seemed to try to be quite precise while typing at the keyboard where they had total control over any errors committed as opposed to voice input where the T600 might not recognize their utterance.

As far as time was concerned, the total time required for all the subjects' typing inputs was 254.35 minutes, 286.17 minutes for buffered voice and 585.7 minutes for un-buffered voice. Therefore typing was 11.1 percent faster

than buffered voice, and 56.6 percent faster than unbuffered voice input.

C. RESULTS FOR SCENARIO TIMES

Table 1 shows the time in minutes required for each subject to input the list of 20 commands by the three entry methods, and Table 2 shows this data for the five groups of commands. An analysis of variance [14] was performed on this time data and Table 3 gives the statistical results. (The task of inputting either the 20 commands or the five groups of commands is hereafter referred to as the Task Type.)

Table 3 shows that there was a statistically significant difference (at the α = .10 level) in time for experience level, as can be seen in Figure 3. (An α level of .10, for example, means that there is only a 10 percent chance or less that it is wrong to say there was a significant difference in certain conditions.) The experienced subjects were able to input the commands faster via all three entry methods, and most noticeably by unbuffered voice where the average time climbed most steeply for the inexperienced subjects.

Table 3 also shows that there was a significant difference (α = .01) in time for entry method. A range test [15] showed that there was a significant improvement in time with both typing and buffered voice over unbuffered voice, and that there was no difference between typing and buffered voice as far as time is concerned. These results are shown in Figure 4.

Table 1. Time for 20 Commands

SUBJECT	TYPE	UNBUFFERED VOICE	BUFFERED VOICE
1	11.97	20.05	12.80
2	5.55	20.22	16.62
3	7.42	12.35	7.52
4	20.37	28.77	11.72
5	9.33	15.00	10.43
6	9.43	6.80	7.82
7	15.40	40.32	14.40
8	8.67	76.88	15.82
9	9.47	18.80	9.40
10	12.67	20.57	13.13
11	9.32	11.78	10.00
12	11.15	36.40	10.80

Table 2. Time for Five Groups of 4 Commands Each

SUBJECT	TYPE	UNBUFFERED VOICE	BUFFERED VOICE
1	10.27	22.40	11.73
2	8.80	20.97	12.88
3	9.65	10.32	9.23
4	14.88	18.03	9.62
5	8.10	11.78	9.05
6	10.27	10.48	8.22
7	11.35	44.23	16.98
8	8.07	56.18	17.05
9	9.42	23.22	11.28
10	12.95	15.20	10.57
11	8.52	21.85	14.85
12	11.32	23.10	13.85

Table 3. Analysis of Variance for Time

SOURCE	df	MS	F
Between Subjects	11		
EL (experience level)	1	700.1282	3.8287*
$Error_b$	10	182.8630	
Within Subjects	60		
EM (entry method)	2	1392.5246	10.9110**
TT (task type)	1	15.0152	.8093
EL x EM	2	432.8107	3.3912*
EL x TT	1	.0612	.0033
EM x TT	2	18.8148	1.312
EL x EM x TT	2	3.0497	.2126
$Error_1$	20	127.6252	
$Error_2$	10	18.5524	
$Error_3$	20	14.34	

* $\rho<.10$
** $\rho<.01$

df: degrees of freedom
MS: Mean Square
F: F test ratio

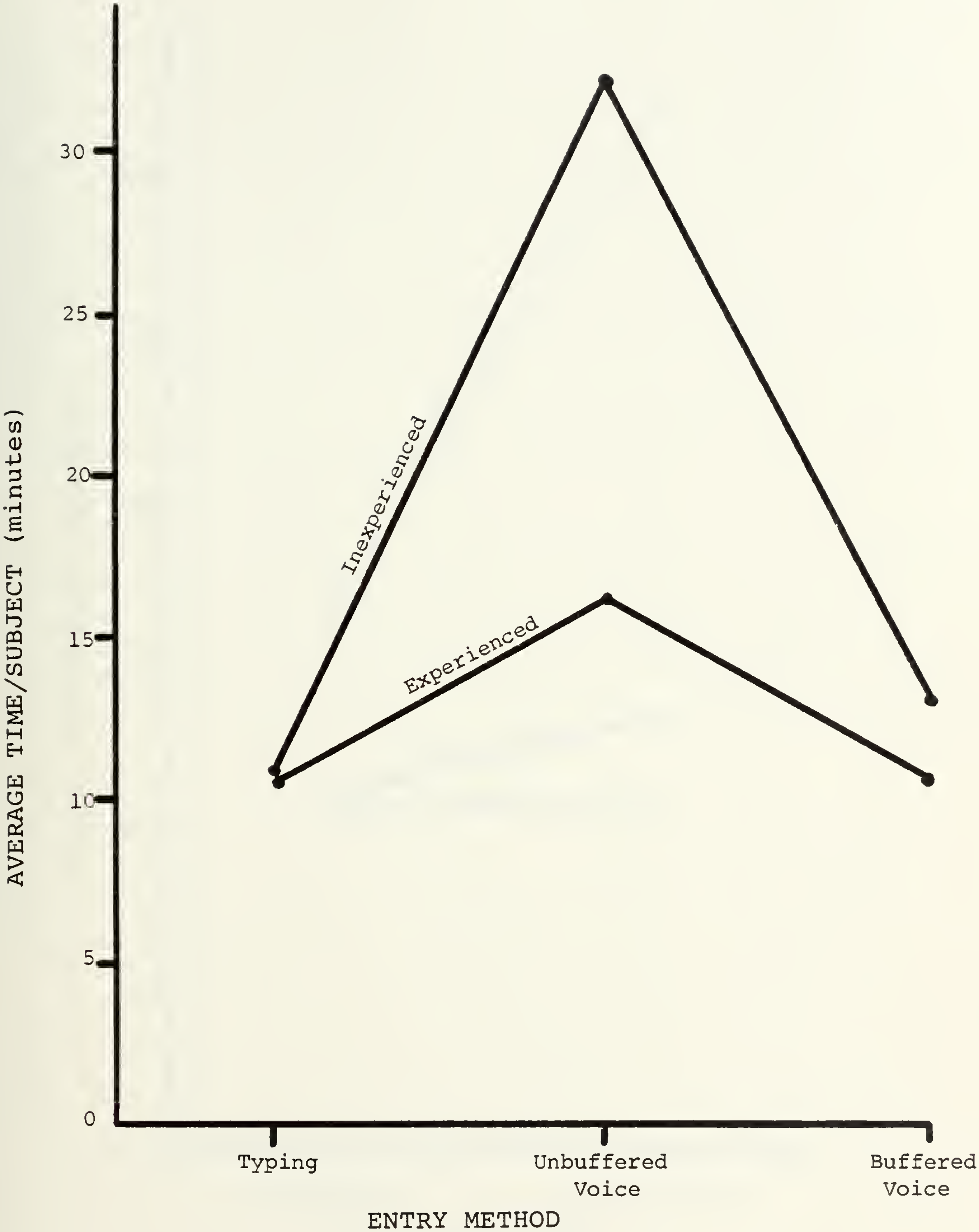


Figure 3. Average Time for Different Entry Methods

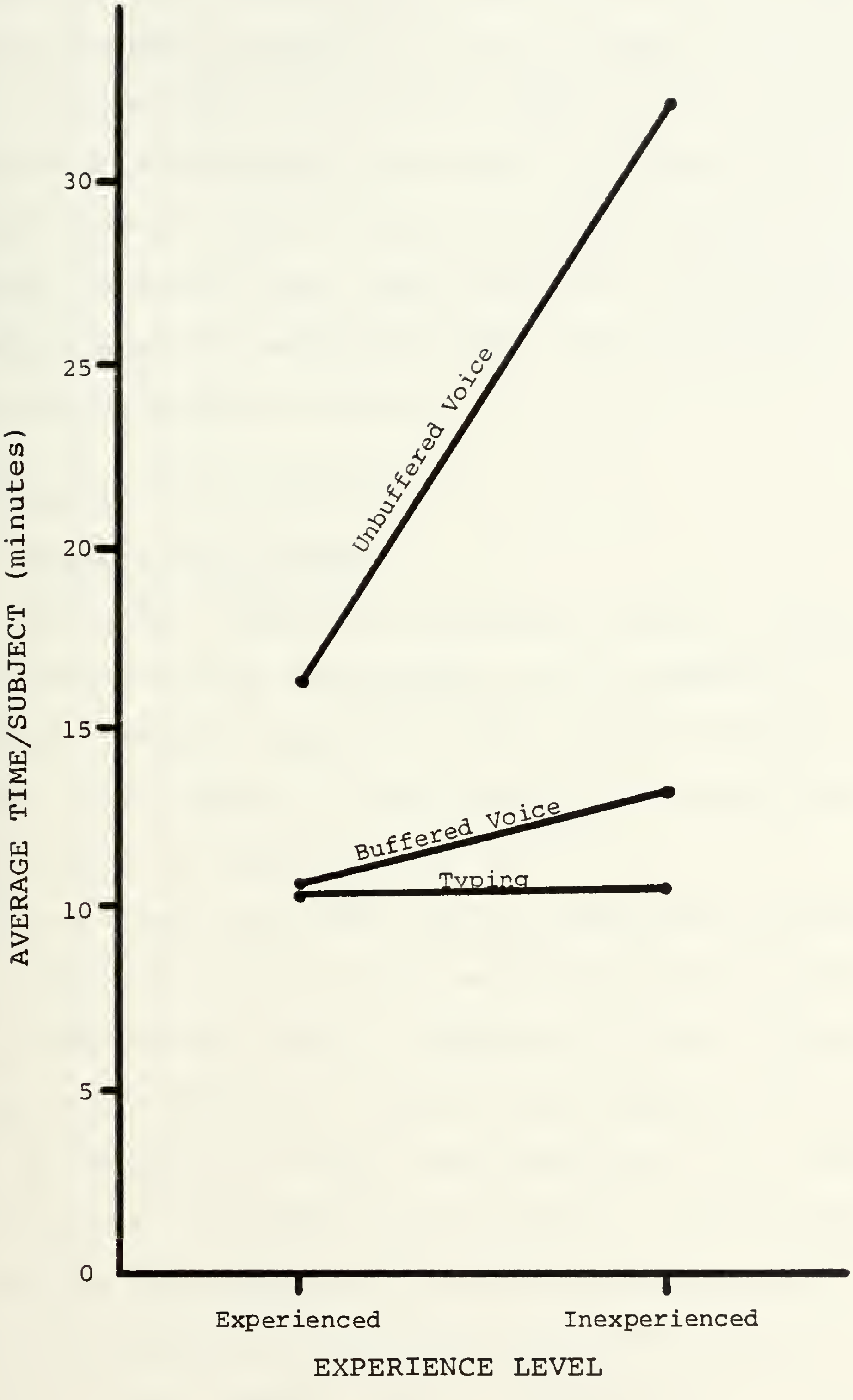


Figure 4. Average Time for Two Experience Levels

There was also significant experience level-by-entry method interaction shown in Table 3. This is shown in both Figures 3 and 4 and was due mainly to the effect of the inexperienced subjects with unbuffered voice where the average time increased much more quickly than it did for the experienced subjects.

Table 3 further shows that there was no difference in the two task types with respect to time. There was also no other significant interaction shown.

D. RESULTS FOR INPUT ERRORS

1. Recognition Errors

The total number of recognition errors for each subject in the two voice entry modes for 20 commands is given in Table 4. Table 5 shows this data for the five groups of commands. The results of the analysis of variance for this data are given in Table 6.

Table 6 shows that there was no significant difference in either experience level, entry method or task type with respect to recognition errors. Although it is not surprising that the entry method and the task type make no difference as far as recognition errors are concerned, it is somewhat surprising that experience level does not. The author would have thought the opposite to be true, with experienced subjects having significantly fewer recognition errors.

Table 6 does, however, show a significant ($\alpha = .05$) interaction between entry method and task type as depicted in

Table 4. Recognition Errors for 20 Commands

SUBJECT	UNBUFFERED VOICE	BUFFERED VOICE
1	19	18
2	24	62
3	5	2
4	28	8
5	16	8
6	2	3
7	69	31
8	81	26
9	9	5
10	6	6
11	5	16
12	29	20

Table 5. Recognition Errors for Five Groups of 4 Commands Each

SUBJECT	UNBUFFERED VOICE	BUFFERED VOICE
1	25	14
2	15	43
3	4	7
4	13	6
5	13	15
6	6	3
7	52	33
8	70	24
9	17	15
10	5	7
11	16	43
12	14	24

Table 6. Analysis of Variance for Recognition Errors

SOURCE	df	MS	F
Between Subjects	11		
EL (experience level)	1	1452	1.5332
$Error_b$	10	946.9916	
Within Subjects	36		
EM (entry method)	1	225.3333	.5114
TT (task type)	1	4.0833	.0510
EL x EM	1	420.0833	.9535
EL x TT	1	48	.60
EM x TT	1	108	5.1695*
EL x EM x TT	1	80.0834	3.8332**
$Error_1$	10	440.5583	
$Error_2$	10	79.9916	
$Error_2$	10	20.8916	

* $p<.05$
** $p<.10$

df: degrees of freedom
MS: Mean Square
F: F test ratio

Figure 5. Although the average number of recognition errors was greater for 20 commands than for the five groups in unbuffered voice, the opposite was true for buffered voice. There is also a significant three-way interaction shown in Table 6 between experience level, entry method and task type. This interaction is shown in Figure 6.

2. Operator Errors

Operator errors were all errors other than those caused by the T600 voice recognition unit. This included such things as typing and spelling errors in the typing mode, and basically forgetting the various ground rules, and therefore causing mistakes, while using the voice modes. Table 7 shows the number of operator errors committed while inputting the list of 20 commands, and Table 8 gives this information for the groups of commands. Table 9 shows the results of the ANOVA performed on this data.

Table 9 shows a statistically significant difference at the $\alpha = .05$ level in operator errors for entry method. A range test showed a significant decrease in operator errors for buffered voice as compared to both unbuffered voice and typing. The range test showed no difference between the typing and unbuffered voice modes with respect to operator errors. This is shown in Figure 7 where buffered voice has fewer operator errors than the other input methods for both experience levels.

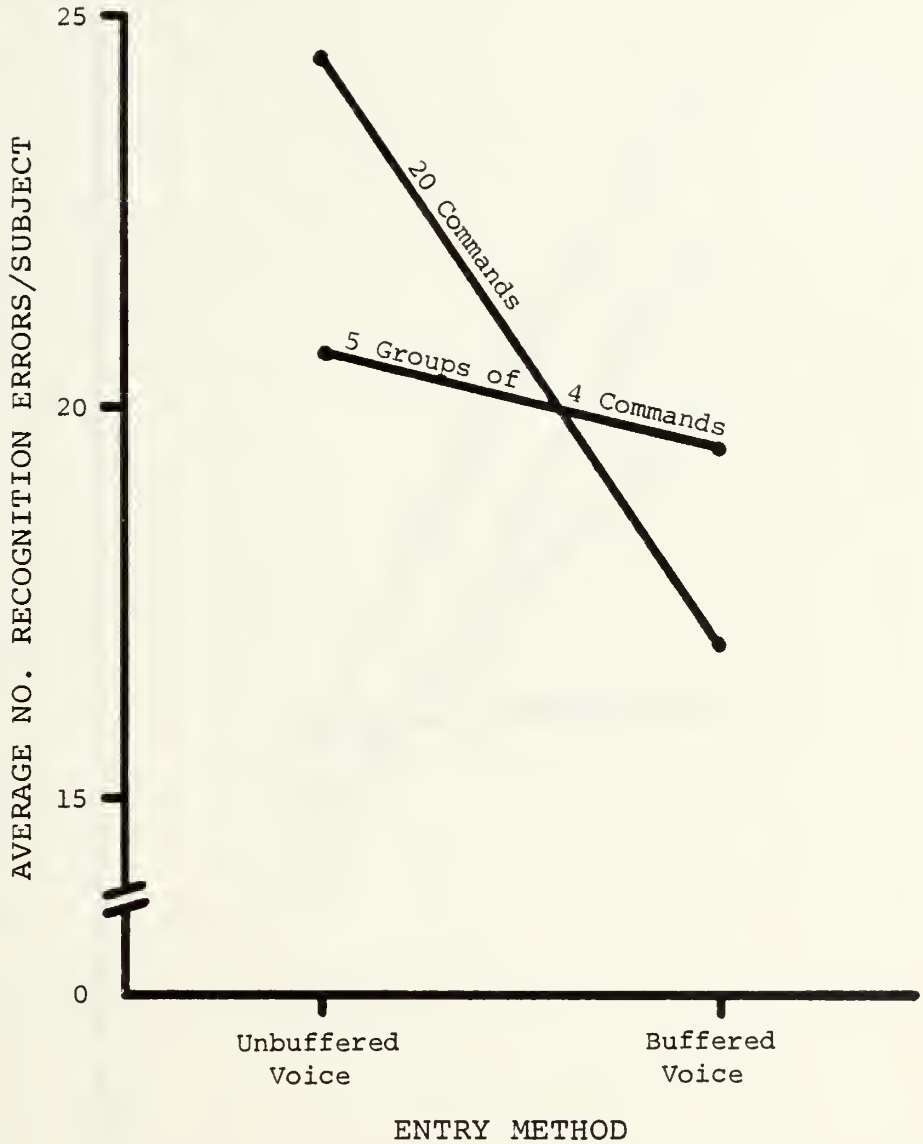


Figure 5. Average Number of Recognition Errors for Different Entry Methods

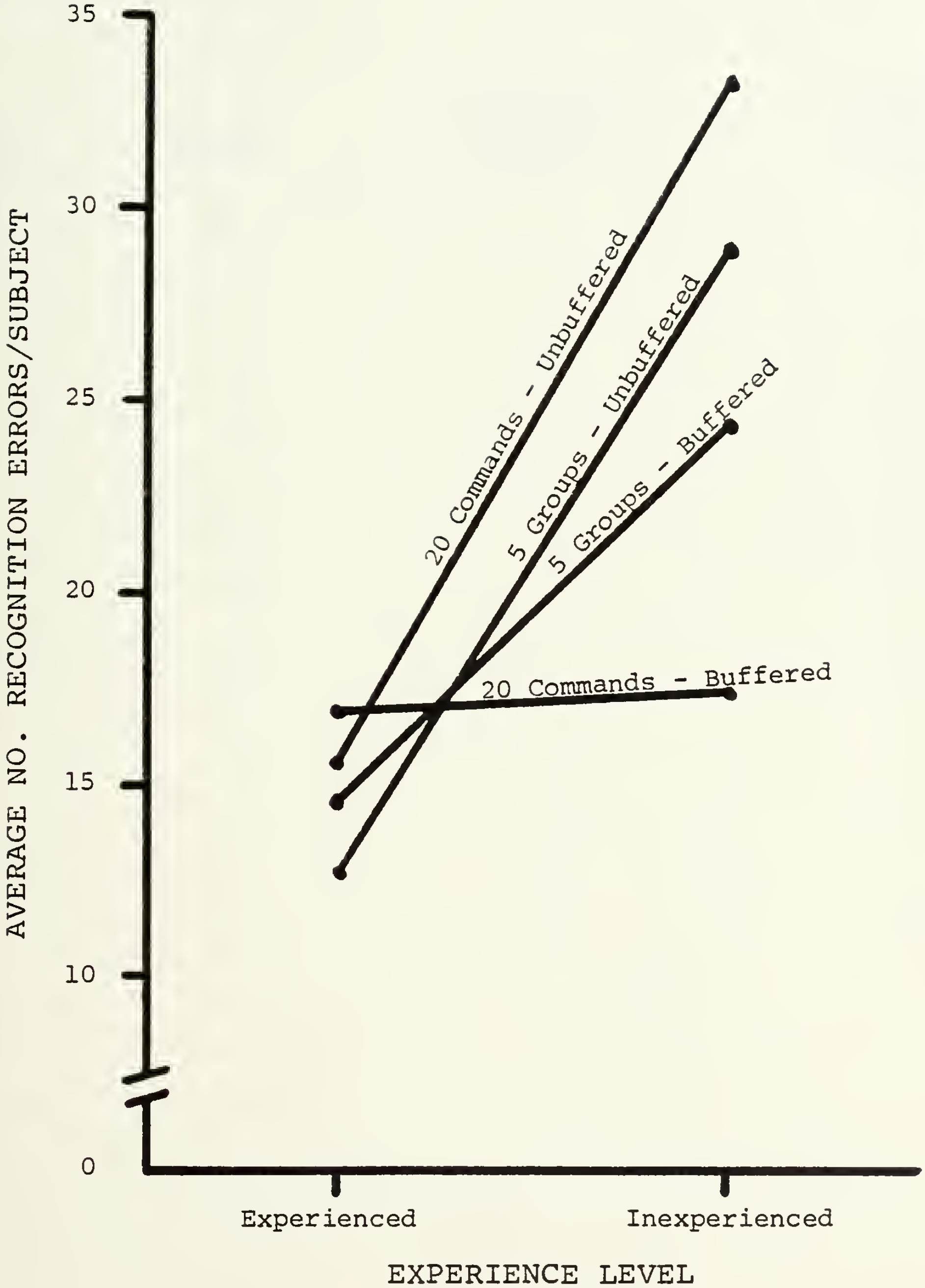


Figure 6. Average Number of Recognition Errors for Different Experience Levels

Table 7. Operator Errors for 20 Commands

SUBJECT	TYPE	UNBUFFERED VOICE	BUFFERED VOICE
1	13	10	8
2	1	9	6
3	4	8	4
4	6	15	4
5	4	4	3
6	10	1	3
7	7	6	1
8	9	11	9
9	5	4	2
10	4	2	3
11	3	6	4
12	5	3	2

Table 8. Operator Errors for Five Groups of 4 Commands Each

SUBJECT	TYPE	UNBUFFERED VOICE	BUFFERED VOICE
1	11	7	6
2	10	12	7
3	13	8	5
4	6	5	6
5	3	2	1
6	16	10	3
7	4	3	5
8	9	8	5
9	4	5	4
10	9	3	2
11	7	15	5
12	6	1	5

Table 9. Analysis of Variance for Operator Errors

SOURCE	df	MS	F
Between Subjects	11		
EL (experience level)	1	46.7222	1.8772
$Error_b$	10	24.8888	
Within Subjects	60		
EM (entry method)	2	52.0972	5.3311*
TT (task type)	1	14.2222	1.0314
EL x EM	2	3.3472	.3425
EL x TT	1	.2223	.0161
EM x TT	2	8.5972	1.3147
EL x EM x TT	2	5.8472	.8942
$Error_1$	20	9.7722	
$Error_2$	10	13.7888	
$Error_3$	20	6.5388	

*$p < .05$

df: degrees of freedom
MS: Mean Square
F: F test ratio

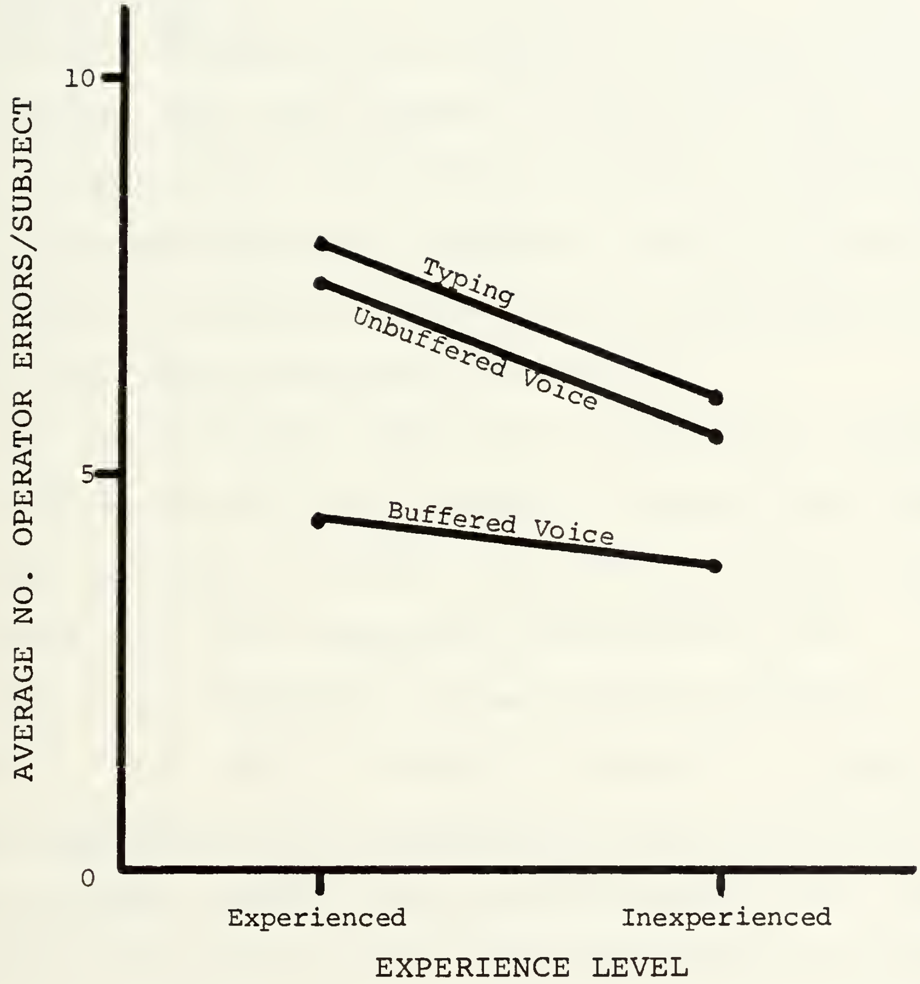


Figure 7. Average Number of Operator Errors for Different Experience Levels

Table 9 shows that there is no significant difference in operator errors over either experience level or task type. There are also no significant interactions shown in the table.

3. Total Errors

The total errors are the sum of the recognition and operator errors. The total number of errors for each subject is given in Table 10 for the task of entering 20 commands, and in Table 11 for the groups of commands. As for the other types of errors an analysis of variance was performed on this data, with the results presented in Table 12.

The results of the ANOVA show a significant difference in total errors for entry method. A range test showed a significant decrease in total errors for the typing mode when compared with both unbuffered and buffered voice. There was no significant difference between the two different voice input modes. This result is shown in Figure 8. IT MUST BE REMEMBERED, HOWEVER, THAT THE TYPING MODE DID NOT INCLUDE RECOGNITION ERRORS, WHEREAS THE TWO VOICE MODES DID. THEREFORE, FOR THE VOICE MODES TOTAL ERRORS ARE THE SUM OF OPERATOR AND RECOGNITION ERRORS, WHILE FOR TYPING TOTAL ERRORS ARE THE SAME AS OPERATOR ERRORS. THIS CAN BE SEEN BY COMPARING THE CURVES FOR TYPING IN FIGURES 7 AND 8 WHICH SHOW TYPING WITH THE EXACT SAME TREND BECAUSE THERE COULD BE NO VOICE RECOGNITION ERRORS UNDER THE TYPING METHOD.

Table 10. Total Errors for 20 Commands

SUBJECT	TYPE	UNBUFFERED VOICE	BUFFERED VOICE
1	13	29	26
2	1	33	68
3	4	13	6
4	6	43	12
5	4	20	11
6	10	3	6
7	7	75	32
8	9	92	35
9	5	13	7
10	4	8	9
11	3	11	20
12	5	32	22

Table 11. Total Errors for
Five Groups of 4 Commands Each

SUBJECT	TYPE	UNBUFFERED VOICE	BUFFERED VOICE
1	11	32	20
2	10	27	50
3	13	12	12
4	6	18	12
5	3	15	16
6	16	16	6
7	4	55	38
8	9	78	29
9	4	22	19
10	9	8	9
11	7	31	48
12	6	15	29

Table 12. Analysis of Variance
for Total Errors

SOURCE	df	MS	F
Between Subjects	11		
EL (experience level)	1	589.3889	.7749
$Error_b$	10	760.5722	
Within Subjects	60		
EM (entry method)	2	3107.1805	7.6051*
TT (task type)	1	4.5	.0524
EL x EM	2	442.1805	1.0822
EL x TT	1	26.8888	.3136
EM x TT	2	75.5416	1.8751
EL x EM x TT	2	66.2639	1.6448
$Error_1$	20	408.5638	
$Error_2$	10	85.7277	
$Error_3$	20	40.2861	

*$\rho<.01$

df: degrees of freedom
MS: Mean Square
F: F test ratio

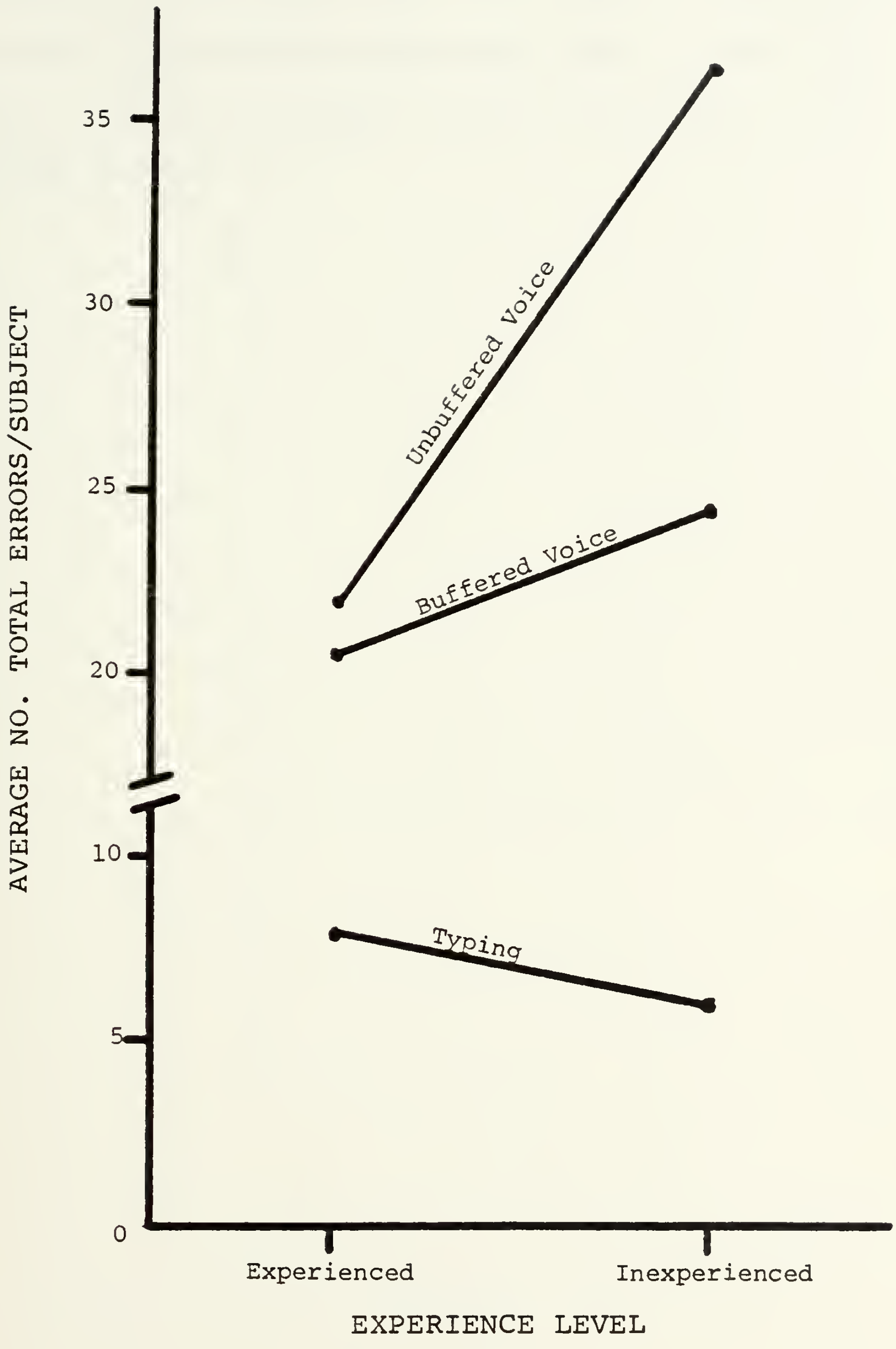


Figure 8. Average Number of Total Errors for Different Experience Levels

Table 12 shows that there is no significant difference in total errors over either experience level or task type. In addition, there are no significant interactions in the area of total errors.

V. CONCLUSIONS AND RECOMMENDATIONS

A. EXPERIMENTAL CONCLUSIONS

Based on the results of this experiment, twelve test subjects were able to input WES commands to the war game faster and with fewer total errors using the manual typing input mode than with two voice input modes. Experienced voice subjects input the commands faster than the inexperienced subjects, but experience level made no difference as far as the total number of errors committed was concerned. Typing was significantly better as far as total errors, but there was no statistical difference between typing and buffered voice modes as far as time was concerned. Finally, for time and total errors, it made no difference which of the two task types was being performed.

The results suggest that manual input is certainly superior to unbuffered voice, and in some respects to buffered voice input in this experiment. However, the author feels that this must be qualified by looking at the unique situation in which the input methods were being used. WES commands are very formatted and must be entered with no errors. This requirement caused many commands to be rejected and resulted in the definite infeasibility of using unbuffered voice input with WES. It simply took too long and resulted in too many errors. The buffered voice mode held its own

with typing when considering input time, and it was actually better than typing for operator errors.

In a task such as running WES, when the goal must be perfection in entering all player commands in order to actually play the game, if the time required for two different input methods is the same, then it appears that their error rates are insignificant. In this experiment there was no statistical difference in time for the typing and buffered voice input methods, so the fact that buffered voice had more total errors really makes no difference. The lists of commands were input and accepted by WES in the same amount of time regardless of errors.

There are also possible intangible benefits associated with the use of voice input to a computer, whatever its purpose might be. One such benefit might be the ability of supervisors or commanders to hear what is being told to or asked of a computer while they are still engaged in other activities. This would eliminate several people leaning over the shoulder of the operator trying to see what he is typing into the computer, allowing the operator to perform his job more easily and probably increasing the total efficiency in the work area.

B. RECOMMENDATIONS FOR FURTHER STUDY

Voice recognition, although very promising in many fields, certainly is not the panacea in all areas of input to

computers. This can be seen by the unbuffered voice results with WES. This should not, however, slow down the research being done in the field of voice recognition. Studies cited earlier point out very promising uses of voice recognition. The author believes that further research should be done, using the buffered voice mode, during WES games to test its validity in actual use. This could be done quite easily as thesis research work at NPS, in the C^3 laboratory course at NPS, or in conjunction with scheduled war games involving NPS, CINCPACFLT and NOSC.

In this experiment the subjects were divided into experienced and inexperienced groups as far as voice recognition systems were concerned. However, the fact that the subjects were not experienced with WES was never taken into account. Another possible experimental factor might be to compare the results of experienced and inexperienced WES users. Although increasing the variables like this would make it more difficult to find the required number of subjects, this could be done at NPS in the C^3 curriculum where the students take almost all of the same classes for six quarters.

Further research also should be done in the NPS RSM, perhaps in conjunction with the WES games proposed above, to study the effects of background and ambient noise on the reliability of the voice recognition equipment. There will surely be this noise problem in any operational use of voice equipment in a command center, CIC or aircraft, and this

could easily be simulated by introducing noise while using the equipment at NPS.

Research into the possible uses of voice recognition equipment in aircraft, intelligence, war gaming and other operational uses is presently ongoing at NPS. These efforts will result in much new information on the uses and drawbacks of automatic voice recognition. Truly operational, rather than merely scholarly and scientific study in this field must be continued if we are to reap any benefits from this new technology available today. This should be an ongoing endeavor at NPS, and in the C^3 curriculum particularly where there is such promise and demand for this type of technology today and in the future.

APPENDIX A

VOICE STUDIES AT NPS

This thesis is one of several voice recognition research projects conducted for Professor G. K. Poock at NPS over the last several years. The complete list, in addition to this thesis, includes:

Armstrong, J. W., The Effects Of Concurrent Motor Tasking On Performance Of A Voice Recognition System, Masters Thesis, Naval Postgraduate School, Monterey, 1980.

Batchellor, M. P., Investigation Of Parameters Affecting Voice Recognition Systems In C^3 Systems, Masters Thesis, Naval Postgraduate School, Monterey, 1981.

Bragaw, P. H., Investigation Of Voice Input For Constructing Joint Chiefs Of Staff Emergency Action Messages, Masters Thesis, Naval Postgraduate School, Monterey, 1981.

Jay, G. T., An Experiment In Voice Data Entry for Imagery Intelligence Reporting, Masters Thesis, Naval Postgraduate School, Monterey, 1981.

Naval Postgraduate School Report NPS54-80-010, The Effects Of Certain Background Noises On The Performance Of A Voice Recognition System, by R. Elster, September 1980.

Naval Postgraduate School Report NPS55-80-016, Experiments With Voice Input For Command And Control: Using Voice Input To Operate A Distributed Computer Network, by G. K. Poock, April 1980.

Naval Postgraduate School Report NPS55-81-003, Examination Of Voice Recognition System To Function In A Bilingual Mode, by D. E. Neil and T. Andreason, February 1981.

Taggart, J. L. and Wolfe, C. D., Speech Recognition As An Input Medium For Preflight In The P3C Aircraft, Masters Thesis, Naval Postgraduate School, Monterey, 1981.

APPENDIX B

WES VOCABULARY

A. BASIC WES WORDS

one	two
three	four
five	six
seven	eight
nine	zero
a	s
e	air
all	altitude
at	attack
back	barrier
bearing	bingo
blue	by
cancel	carriage return
course	cover
degrees	delay
designate	distance
dive	drop
east	end
enemy	envelope
execute	exsup
find distance from	fire

fire a	for
forces	friendly
go	guide
heading	help
if attacked	kill line
kill word	label
launch	lay a barrier from
lay a minefield from	list
maneuver delay	map
minefield	minutes
name	neutral
north	now
of	off
on	on contact
orange	orders
other	own
pass control of	place
place a circle	place a marker
player	plot
point	position
pounds from	probability
probability of detection	proceed
refuel	report
self	send it
sensor delay	south
space	speed

station	submarine
surface	target
time	to
track	unknown
using	west
what is the	with

B. SCENARIO SPECIFIC WES WORDS

A181	A182
A183	A6E1
A6E2	ALR59
ARM	ASMD
ASROC	AWG9
BERKELEY	Blue1
BPS14	BQQ3
CBU24	E2C
EA3	EA6B
ENTERPRISE	ESM
F14B	for BERKELEY
for ENTERPRISE	for STURGEON
G554	HARM
Harpoon	KA6D
Maverick	MK46
MK48	MK82
MK83	MK84

Phoenix	Redeye
RF18B	Sea Sparrow
Sidewinder	SLQ17
SLQ32	Sonobuoy Active
Sonobuoy Passive	Sparrow
SPN43	SPS10
SPS40	SPS48
SPS49	SQS23
STURGEON	Tartar2
Tomahawk	Walleye
Walleye2	WLR6

APPENDIX C

TEST SUBJECTS' BACKGROUNDS

Subject	Service	Sex	Position	Voice Experience	(wpm) Typing Ability
1	USAF	M	student	experienced	32
2	USN	F	student	experienced	59
3	USAF	M	student	experienced	46
4	USN	M	student	experienced	17
5	USN	F	faculty	extensive	34
6	Civ	M	faculty	extensive	39
7	USN	M	student	minimal	21
8	USAF	M	student	minimal	39
9	USN	M	student	minimal	38
10	USAF	M	student	minimal	37
11	USA	M	student	minimal	37
12	USN	M	student	minimal	26

APPENDIX D

TYPING ABILITY TEST

Because they have often learned to know types of architecture by decoration, casual observers sometimes fail to realize that the significant part of a structure is not the ornamentation but the body itself. Architecture, because of its close contact with human lives, is peculiarly and intimately governed by climate. For instance, a home built for comfort in the cold and snow of the northern areas of this country would be unbearably warm in a country with weather such as that of Cuba. A Cuban house, with its open court, would prove impossible to heat in a northern winter.

Since the purpose of architecture is the construction of shelters in which human beings may carry on their numerous activities, the designer must consider not only climatic conditions, but also the function of a building. Thus, although the climate of a certain locality requires that an auditorium and a hospital have several features in common, the purposes for which they will be used demand some difference in structure. For centuries builders have first complied with these two requirements and later added whatever ornamentation they wished. Logically, we should see as more additions, not as basic parts, the details by which we identify architecture.

Line Number	wpm (errors allowed) 1st typing of the exercise (5 minutes maximum)	2nd
1	2( )	52(7)
2	5( )	54(7)
3	7( )	56(8)
4	9( )	59(8)
5	12( )	61(9)
6	14( )	64(9)
7	16( )	66(10)
8	18( )	68(10)
9	21( )	71(11)
10	23( )	73(11)
11	26( )	76(12)
12	28( )	78(12)
13	30( )	80(12)
14	33( )	---
15	35( )	---
16	38( )	---
17	40(3)	---
18	42(4)	---
19	44(5)	---
20	47(6)	---
21	49(6)	---

APPENDIX E

LIST OF 20 WES COMMANDS

1. For Enterprise launch 2 F14B course 090 altitude 15000 bingo 999 name 1F14B.
2. For Berkeley attack enemy surface on contact using G554.
3. Find distance from Enterprise to 42N 57W.
4. For Sturgeon course 090 speed 15.
5. Place a circle Enterprise 150 time 15 999.
6. For Sturgeon report all surface using BQQ3.
7. For Berkeley fire a harpoon target enemy surface sensor delay 2 heading 120.
8. Pass control of 1F14B to Bluel.
9. For 1F14B lay a minefield from 26N 42W bearing 135 distance 10 using MK82.
10. Place a marker 57N 71W time 23 300.
11. For 1F14B proceed course 215 distance 115.
12. For Berkeley station bearing 000 distance 3 guide Enterprise.
13. For Sturgeon attack enemy submarine on contact using MK48.
14. For 1F14B altitude 20000 speed 600 course 090.
15. For Enterprise report all air using SPS49 time 00 999.

16. For 1F14B attack enemy air <u>on contact</u> using Phoenix.

17. <u>For Enterprise</u> launch 1 KA6D course 000 altitude 10000 bingo 120 name 1KA6D.

18. Plot all surface Enterprise 100.

19. <u>For Berkeley</u> report enemy forces using SLQ32 time 00 120.

20. For 1F14B refuel 6000 <u>pounds from</u> 1KA6D.

APPENDIX F

FIVE LISTS OF FOUR WES COMMANDS

I.

1. For Berkeley attack enemy surface on contact using G554.
2. Find distance from Enterprise to 42N 57W.
3. For Berkeley fire a harpoon target enemy surface sensor delay 2 heading 120.
4. Plot all surface Enterprise 100.

II.

1. For Sturgeon course 090 speed 15.
2. Place a circle Enterprise 150 time 15 999.
3. For Enterprise launch 2 F14B course 090 altitude 15000 bingo 999 name 1F14B.
4. For Berkeley report enemy forces using SLQ32 time 00 120.

III.

1. Pass control of 1F14B to Bluel.
2. Place a marker 57N 71W time 23 300.
3. For Berkeley station bearing 000 distance 3 guide Enterprise.
4. For Enterprise launch 1 KA6D course 000 altitude 10000 bingo 120 name 1KA6D.

IV.

1. For Sturgeon report all surface using BQQ3.

2. For 1F14B proceed course 215 distance 115.

3. For Sturgeon attack enemy submarine on contact using MK48.

4. For 1F14B attack enemy air on contact using Phoenix.

V.

1. For 1F14B lay a minefield from 26N 42W bearing 135 distance 10 using MK82.

2. For Enterprise report all air using SPS49 time 00 999.

3. For 1KA6D altitude 20000 speed 600 course 090.

4. For 1F14B refuel 6000 pounds from 1KA6D.

APPENDIX G

INSTRUCTIONS FOR SUBJECTS

- You will be inputting a set of 20 commands and five sets of four commands each to the WES game by typing, unbuffered and buffered voice.
- If you make a mistake in either typing or unbuffered modes, carriage return right away to save time since it can't be corrected. Then reenter the command correctly.
- In the buffered mode you can use kill word or kill line to make changes before entering your commands.
- Input the commands as quickly as possible since you are being timed, but they must also be 100 percent accurate and accepted by WES.
- Remember to input a "space" after numbers you enter. All words automatically have a space with them.
- Remember that the words "for" and "to" were trained as "for the" and "to the" to differentiate them from the numbers 4 and 2. If you forget "the," the utterance will be recognized as the number.
- All phrases which were trained as a single utterance (e.g., pass control of) are highlighted in yellow so you won't have to try to remember the phrases. Remember to speak them as a single utterance.

- Ensure the microphone is correctly positioned and if it moves stop and reposition it.
- The green READY light must be on for the T600 to accept your utterance. Allow a short pause between each utterance for it to come back on.
- Use of a forceful tone of voice produces the best results, and try not to draw out the utterance by a breathing noise at the end.

APPENDIX H

PRACTICE VOICE COMMANDS

1. For E2C lay a barrier from 36N 76W bearing 180 distance 100 using sonobuoy passive.
2. For 1F14B bingo.
3. For EA3 proceed position 27N 183E.
4. For 1F14B speed 1200 course 090 altitude 10000.
5. Designate Enterprise 77.1.

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U.S. Army Human Eng Lab
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Ohio State University
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Industrial Engineering
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SRL-Human Factors Eng.
2800 Indian Ripple Road
Dayton, OH 45440

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Comp. Sci & Appl. Math Dept.
Lawrence Berkeley Lab
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Code 8141
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R 84-17
Merck and Co.
Box 2000
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239-3
NASA
Moffett Field, CA 94035

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Code 3522
NUSC
Newport, RI 02840

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RADC/IRAA
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DIRNSA ATTN: R542
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Ohio 45433

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Acoustical Sciences Div
NAMRL
NAS
Pensacola, FL 32508

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Directorate of Training
U.S. Army Signal Ctr
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6021
NADC
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NUSC
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FLTMATSUPPOFFICE
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AFFDL/FGR
Wright-Patterson AFB
Ohio 45433

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Code 4043
NADFC
Warminster, PA 18974

63. LT. Jeff Woodard 1
RADC/IRAA
Griffiss AFB
Rome, N.Y. 13441

64. CDR Chuck Hutchins 1
NAVAIRSYSCOM
AIR-340F
Jefferson Davis Highway
Arlington, VA 20360

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AFAMRL/BBA
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Ohio 45433

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Code 330
NAVELEX
2511 Jefferson Davis Highway
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Code 330
NAVELEX
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Dept. of National Defence
101 Colonel By Drive
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RADC/IRAA
Griffiss AFB
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